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Methodology for building the optimal test bench of software and hardware complexes of control systems

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Abstract. The paper considers the issue of creating unified approaches to building test stands for software and hardware control systems. A universal architecture of the test bench is proposed and the author's method of constructing optimal test stands, obtained as a result of research in the field of complex automation of the test process, is described. The algorithm of directed search for the best test stand configuration is considered by example and the results of the implementation of the proposed method are demonstrated.

Keywords: automatic control system, test bench, analysis of the development process, optimal test stand, hardware and software complex.

1. Introduction

In the modern world, much attention is paid to the problems of shifting the time of detecting errors in the design and development of new samples of rocket and space technology products to earlier stages. An important role in solving this problem is played by the stage of ground-based experimental testing. At this stage, in one hand, the product operates in conditions as close as possible to normal operating modes, and in the other hand, developers are provided with a full set of tools for diagnosing and verifying the correct operation. To solve the maximum number of tasks on the test bench for a given time of testing, it is necessary to carry out complex automation of this process, which in turn generates the problem of choosing the optimal configuration of the stand (for a set of systems) [1, 2]. It is proposed to solve the problem of choosing the optimal configuration using the method of constructing the optimal test stand of software and hardware complexes of control systems.

2. Computer-aided design system "Testing"

The method of creating test stands for control systems is based on the universal architecture of the test position, and contains recommendations for building an automated test position based on unified automation technologies. The designed automation technologies are combined and implemented as a computer-aided design (CAD) system called "Testing" [3].

CAD "Testing" allows to automate the stage of development of design documentation and software in the development positions, in terms of testing with modeling of various situations (both regular and emergency) and evaluating the results. In addition, CAD is integrated into the overall structure of the control system development by publishing all information about the results of testing (results of modeling and analysis, a list of identified comments) in a single information space (local network of the enterprise). The results of the tests are taken into account when finalizing the design documentation (CAD AltiumDesigner, AutoCAD, Compass, P-CAD) and software (development



environment for Eclipse, Lazarus, etc., CAD software SparxEnterpriseArchitect-software design automation).

An additional advantage of the proposed system is the automation of designing a test position through the use of unified software components that are part of it, as well as software and mathematical software that allows you to determine the optimal structure of the development position at the stage of its creation.

CAD «Testing» is built based on universal architecture of test stand and consists of these components: (figure 1, 2):

- software for determining the optimal configuration of the test stand;
- software package of centralized management;
- system for planning and processing test results;
- test results analysis system;
- universal simulating complex;
- universal configuration file editor.

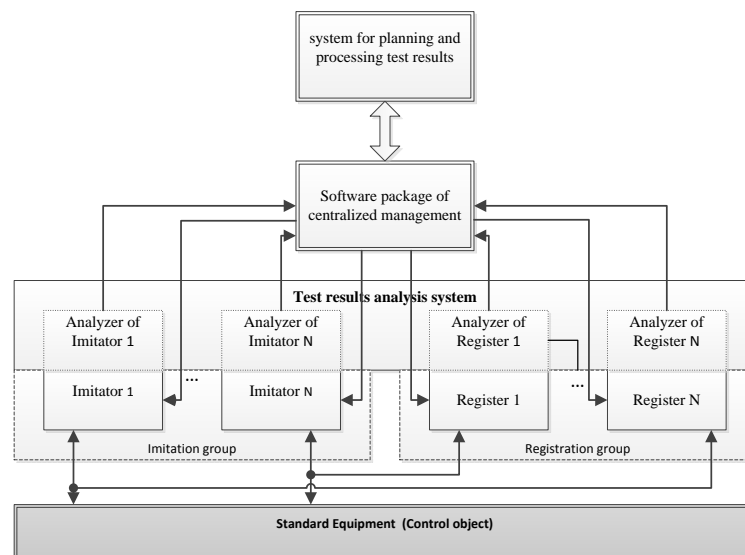


Figure 1. Universal architecture of the test stand

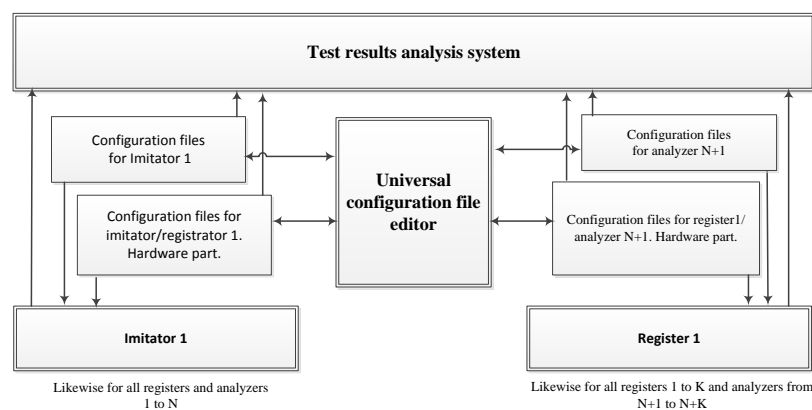


Figure 2. Diagram of forming the test database using the universal configuration file editor

3. Method

The problem of directed search for optimal configuration is related to combinatorial optimization problems, and it can be solved using discrete programming methods. One of the main methods of discrete programming is the dynamic programming method, which is used for directional search for the optimal configuration of the test branch. The possibility and convenience of using this method for solving combinatorial optimization problems, in particular planning problems, is demonstrated in the work of V. V. Shmelev [4].

It should be noted that depending on the scale of the order, the timing of the launch of the stand and the economic capabilities of the enterprise, in some cases it is advisable to use not a complete list of technologies, but a certain set of tools. The developed mathematical model of the automated test stand and the method for evaluating the effectiveness of the test stand together with the directed search algorithm allow you to determine an effective set of technologies for automating the development process based on the specified input data (specifying the application industry and management system), already at the stage of creating a stand.

The method of building an optimal test stand contains the following stages (from obtaining the technical task for the control system (CS):

1. calculation of the parameters of a "typical" development position using the appropriate mathematical model;
2. setting optimization priorities and boundary conditions (terms of position launch, number of specialists involved in creation, amount of funding);
3. in the framework of the algorithm is a directed search selection of independent techniques (group technology) of automation in accordance with the model of the automated developmental position, the formation of a line graph (connections between vertices in the row have, in a summary way (configuration) there is only one vertex of the line) are the possible States (use/non-use) of independent technologies (groups), form the vertices of the graph;
4. under the directed search algorithm the calculation of the efficiency of test stand with a set of automation tools method of evaluation of the effectiveness of developmental positions on the model (including the set priorities), the resulting coefficients for each set are the weights of graph branches, the construction of the state graph, the line containing automation technology with greater efficiency, placed closer to the beginning of the search;
5. search for the optimal branch configuration based on the constructed graph, taking into account the specified restrictions;
6. on the basis of the received configuration of forming a list of standard and technological equipment, development of technical specifications for the CS test stand, ordering the necessary equipment;
7. development of modules for simulation equipment (in accordance with the initial data for interaction with external systems) based on a universal simulation complex – unified system software for simulation equipment (CAD component "Testing»);
8. development of source data (SD) for the mode (cyclograms) by task managers in the source data editor (universal configuration file editor), the developed configuration files (SD in a form suitable for computer processing) are functional software for simulation equipment and control parameters for the test results analysis system;
9. after receiving the equipment and developing the technological software for simulation tools, setting up the required automation tools (centralized control software, test results planning and processing systems, test results analysis systems) and launching the test stand with the optimal configuration for the specified conditions (a set of technological equipment and automation tools) and ensuring the completeness of testing.

An important advantage of the proposed method of constructing a test stand is the possibility of its use in iterative design of the CS (creation of a control system is a lengthy and iterative process), that is, systems of automation of testing can be implemented during mining without recycling the existing (typical) test stand, it is allowed phased implementation. To determine the optimal way to upgrade the

position in the calculations instead of standard model parameters, use the options refining test stand, thus, the method of evaluation of the effectiveness of developmental positions and a method of constructing optimal position could be adapted to the task of modernization and to ensure a gradual start position. This property (the ability to solve the problem of modernization) expands the scope of the methodology, including covering the class of already created test stands.

4. Experimental verification of the algorithm for directional search of the best test stand option

To conduct an experimental verification of the algorithm for directional search for the best test stand option, consider the test stand of control and test equipment of the control system.

The calculation assumes that the centralized control software package (CCSP), the system for planning and processing test results (SPI), the universal simulating complex (USC), the universal configuration file editor (UCFD), the test results analysis system (TRAS), and the method for minimizing technological equipment (minTE) are developed and implemented. Editor of input data (ID) and the mechanism of cyclic conduction modes (mechCyc) – are being developed. The priority of the standard equipment utilization coefficient is 5, the priority of the time for preparing and evaluating test results is 1.5, and all the others are equal to one, since the main optimization task is to minimize the time of testing on the stand, models of standard and automated test stand are used for calculations.

The weights of branches (transitions) that are included in one vertex have the same weight, which is determined by the effectiveness of using the technologies specified in the vertex. As a result of the calculation using the efficiency evaluation method, we get the following weights for vertices:

$d11$ (for $p11$ – CCSP, mechCyc, TRAS) = 1.59

$d12$ ($p12$ – CCSP, TRAS) = 1.48;

$d13$ ($p13$ – CCSP, mechCyc) = 1.58;

$d14$ ($p14$ – CCSP) = 1.44;

$d15$ ($p15$ – TRAS) = 1.01;

$d16$ ($p16$) = 1.

The vertices of the graph (the second group):

$d21$ ($p21$ – USC, UCFD, ID redactor, TRAS) = 1.57

$d22$ ($p22$ – USC, UCFD, TRAS) = 1.47;

$d23$ ($p23$ – USC, UCFD, ID redactor) = 1.01;

$d24$ ($p24$ – USC, UCFD) = 1.04;

$d25$ ($p25$ – TRAS, UCFD, ID redactor) = 1.19;

$d26$ ($p26$ – TRAS, UCFD) = 1.18.

$d27$ ($p27$) = 1.

The vertices of the graph (the third group):

$d31$ ($p31$ – minTE) = 1.01;

$d32$ ($p32$) = 1.

In the fourth step, a state graph is constructed. The state graph for finding the optimal test bench configuration is shown in figure 3.

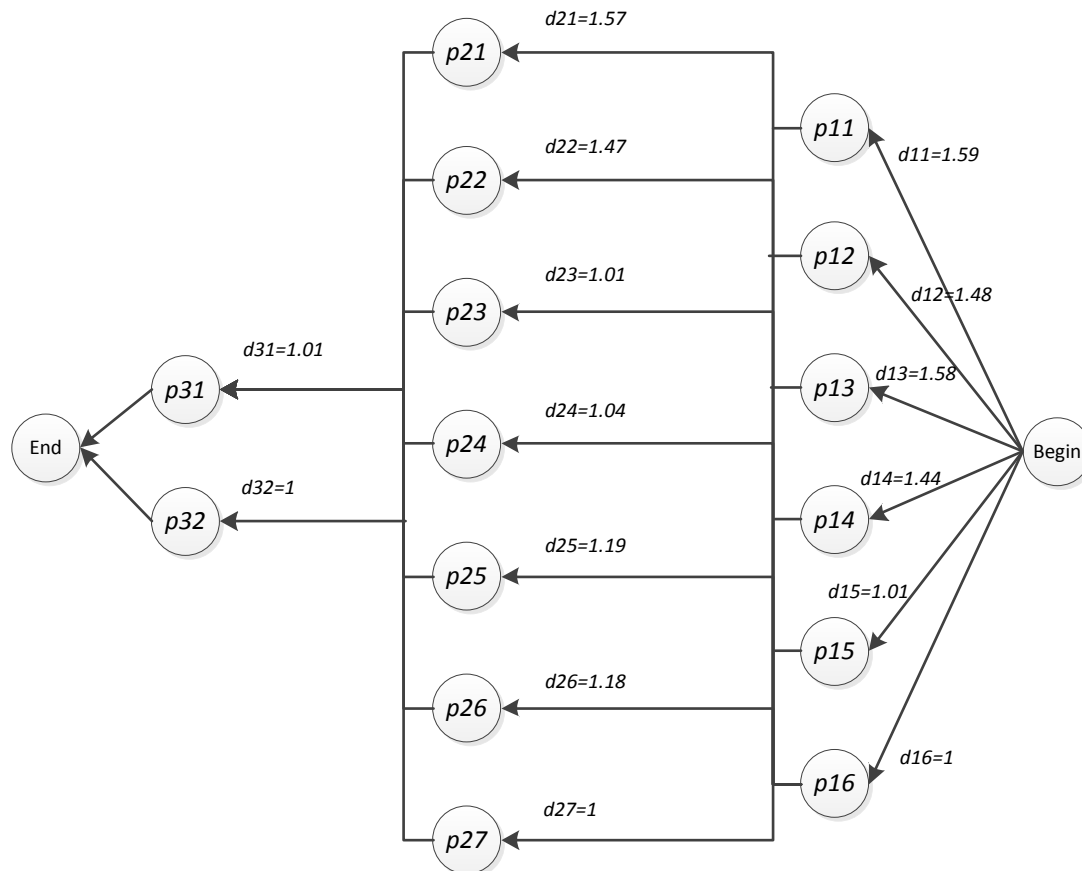


Figure 3. The state graph for finding the optimal test bench configuration

At the fifth step, the boundary search conditions are set. The time limit for launching the stand is 90 business days, the number of developers is no more than 4 people, and the number of analysts is no more than 3 people.

In the sixth step, the optimal structure of the test bench is directly determined, taking into account the specified constraints.

The first step when searching through the graph: find the path with the maximum weight – d_{11} , go to the vertex p_{11} , check the boundary conditions. At the specified time of the stand launch, 3 developers and 1 analyst are required. The boundary conditions are met, we take the vertex p_{11} in the solution.

Second stage: find the path with the maximum weight – d_{21} , go to the vertex p_{21} , check the boundary conditions. At the specified launch date, the stand needs 6 developers and 1 analyst. The boundary conditions are not met, we return to the vertex p_{11} , and exclude the path p_{11} - p_{21} from the search. Find the path with the maximum weight (of the remaining ones) – d_{22} , go to the vertex p_{22} , check the boundary conditions. At the specified time of the stand launch, 3 developers and 1 analyst are required. The boundary conditions are met, we take the vertex p_{22} in the solution.

The third stage: find the path with the maximum weight – d_{31} , go to the vertex p_{31} , check the boundary conditions. At the specified time of the stand launch, 3 developers and 1 analyst are required. The boundary conditions are met, we take the vertex p_{31} in the solution.

The final path of the graph: p_{11} - p_{22} - p_{31} .

Optimal configuration under specified conditions: CCSP, mechCyc, TRAS, weekend, archway, TRAS, minTE.

The obtained optimal configuration of the test stand corresponds to the results calculated in the software "System for calculating the efficiency of the test stand" [5, 6] with a complete search for the specified conditions.

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